



“At the time ARPANET was conceived, computers, programs and communication lines were really costly.

The main objective behind the development then, was to share¹ expensive resources in a robust and efficient manner between geographically distributed users”.

Pål Spilling The European TCP/IP pioneer.



Interviewed on July 28th, 2005 at Stanford (CA) & Oslo (Norway)

Born in October 29th 1934, in Harstad, Norway.

He received his **cand.real.** degree in physics at the University of Oslo in March 1963, and his Ph.D. in experimental nuclear physics from University of Utrecht, the Netherlands in July 1968.

He is a professor with the University of Oslo, assigned to UniK – University Graduate Center at Kjeller, Norway. He has regularly given graduate and undergraduate courses in Computer

Communication and security, from 1985 until today, focusing his actual research on security and wireless communications.

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1963 – 1971; nuclear physics research; universities of Utrecht and Eindhoven.

1972 – 1982; Norwegian Defense Research Establishment NDRE Internet research.

From end 1974 he got involved with the ARPA-funded research program in packet switching and internet technology under the leadership of **Yngvar Lundh**. He was visiting scientist with SRI International in 1979-80 in Menlo Park, California, where he worked on the Packet Radio program. Spilling left NDRE in August 1982 to join the Research Department of the Norwegian Telecommunications Administration (NTA-RD), also at Kjeller. Subsequently he established

¹ A good example is the following: I was participating in speech experiments across the ARPAnet around 1978, and had to modify a voice applications program for our PDP-11/40, located next door to my office at the Norwegian Defense Research Establishment (NDRE). All programming support was hosted at a computer at ISI just north of Los Angeles. The access to these resources went via my terminal connected to NORSAR-TIP and the Telnet program. I could then use a text editor for the modification of the existing program, and then assembling and linking the modified program then using the XNET debugger to upload the program across the network and into the PDP-11/40, and then use the debugging facilities in the XNET to step through the program instruction for instruction, to observe that all was correct. Then came the internet, personal workstations, later Lap-Tops, and then the Web, and the network was transformed into sharing of a global information base.



the first internet node outside USA, interconnected with the US internet.

1982 - 1993; R&D Dept. Telenor; Internet research and fiber communications.

1993 - 2005; Oslo Univ. Professor of Communication networks, security,
and mobile communications.

Do you remember when you had your first contact with a computer?

I had my first real contact with a computer in 1964, when I had to process data from nuclear physics experiments recorded on large rolls of paper tapes. At that time I was working on my PhD research performed at the Dutch nuclear reactor in Petten. The computer was also Dutch, and the program was written by software experts at the Dutch Reactor Centrum.

Some years later I worked with the University of Technology in Eindhoven (Netherlands), also doing experimental research in nuclear physics. I had just received a FORTRAN program, on IBM punch-cards, to help me process and analyze my experimental results, but did not find the output too suitable for my purpose. I then proceeded to modify the output part, which was my first contact with FORTRAN programming. For an experienced programmer this was certainly a trivial task, but not for me. So I was very proud of myself when I had the modifications fixed and running as I wanted.

What was your first contact/experience with ARPANET?

Working with the Norwegian Defense Establishment (NDRE), I was asked in 1975 to participate in the newly established collaboration between NDRE and the american DARPA². I said yes, but did not realize fully what I was doing, considering my background in electronics and nuclear physics. My first task was to participate in a meeting in professor Cerf's group at Stanford University in 1975/76. With my background I did not get much out of the meeting, except that they were discussing details of the TCP protocol.

My first contact with the ARPANET was around the same time. NDRE had agreed to participate in the SATNET project, and in this connection I was put in charge of getting a Norwegian-built computer, located at NDRE, hooked up to the ARPA-node at Kjeller (NORSAR-

² ARPA: Advanced Research Project Agency. Organization whom started and sponsored the ARPAnet.



TIP). Due to the distance to the TIP, we had to use the 1822 VDH interface. I got the interface specifications from BBN in Boston and had a technician at NDRE to build the hardware interface. To my disposition I had a naked computer without any form for operating system, and an assembler, a linker, and a loader program. It was obvious that I first had to develop a multitasking system for the computer and then the driver for the 1822 interface. I was very lucky to get hold of a SRI report by Dave Retz describing the ELF operation system for PDP-11/45. It gave me sufficient understanding of what a multitasking system should do, so that I could proceed to implement my own. After quite a bit of work and frustrations, I hooked up the computer to NORSAR-TIP – to great satisfaction for myself.

In your opinion, what are the key characteristics of Internet?

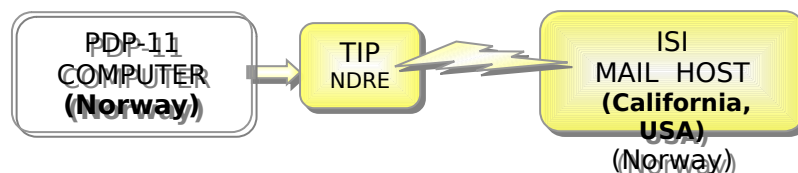
- The internet technology can utilize any underlying network transport technology. This means that any network should be able to connect to any other network without requiring internal modifications
- The packet transport in the network is connectionless. It utilizes adaptive routing, hence the network will be very robust with respect to failures
- no central management and control
- the network is open, meaning that the host computers are always on, with the consequence that the hosts are prone to illegal access and hacker attacks.
- User security is not directly part of the network, but handled outside the network domain. But all security support functionality is directly accessible from the internet, hence vulnerable and prone to hacking
- So as a summary we can say that it is a network of networks, IP tie everything together and is irrelevant what is underneath.

What do you consider the most important milestones in the development of the network?

- The implementation of the ARPANET and the host-to-host communications in the timeframe 1969 till 1972 (and the e-mail, FTP & Telnet developments).
- the TCP testing performed in October 1975 between Stanford University and University College of London.



- Two - network demonstration in 1976 at SRI, between a PRNET³ and ARPANET, and the multi-network demonstration performed in 1977 across SATNET-ARPANET, between Local Area Networks in California (USA), London (UK), and Kjeller (Norway).
- The ARPANET - Internet went through three distinct phases:
 - The basic research and development phase sponsored and supervised by ARPA; The ARPANET - Internet was a closed group from its inception in 1968/69 until 1983 when all ARPANET host converted to the TCP/IP suite of protocols. All participating institutions had to be accepted by ARPA.
 - An interim phase; the network was split in two parts. One part, called MILNET, contained all defense institutions. The other part, still called ARPANET, was open to research institutions in general, not only in the US but also in Europe. At the end of the decennium, NSF⁴ had taken over the responsibility for the main part of the US - network, and with interconnections to networks in Europe and other continents. Many of the regional networks were privatized.
 - The World Wide Web was invented at CERN in 1989, and the first commercial browser was available in 1993. At the same time the restriction on commercial use of the network was lifted, and was the start of the third phase. This resulted in an explosive growth of the internet, when private organizations were allowed to interconnect their own networks.
- From the point of view of Norway, in June 1973 the ARPAnet was installed at NDRE in a computer building, where connected to the satellital connection (TIP) and from there I could connect using Telnet to my mail host⁵ to ISI in California.



- At that time it was very expensive to have a computer or to have the appropriate software. The main philosophy was to make things more reasonable. So one of the more important goals for the ARPAnet was to share resources.

³ PRNET: Packet Radio Network. Network using the "packet switching" paradigm through hertzian radio links.

⁴ NSF: National Science Foundation.

⁵ The ISI mail host, was a Digital (DEC) machine: PDP-11/45.



How did you contribute to the development of the Internet?

As mentioned previously, I implemented the first Norwegian host on ARPANET. Via my primitive host at NDRE, connected to the NORSAR-TIP, I could set up the satellite nodes (SIMPs) to generate artificial traffic in SATNET, and collect traffic measurement data and have those shipped to my host at NDRE for off-line processing. The objective of the SATNET project was to study access control algorithms, in order to devise one suitable for both normal datagram traffic and traffic with real-time properties (voice), and to see what was the most efficient algorithm. [A colleague of mine⁶ and I](#) (from NDRE) participated extensively in these activities, both theoretically and experimentally, establishing the foundations for the SATNET, which was used to connect the ARPAnet with remote sites.

Having a proper access control algorithm in place, SATNET was used as an autonomous network interconnecting local area networks, at NDRE and University College of London, with ARPANET, and proved to be a very suitable arena for developing and refining the internet gateway technology. NDRE was mainly an observer to these activities.

At the end of the SATNET project, 1978-79, I participated in extensive packet speech experiments and demonstrations mainly involving Lincoln Lab (at MIT Boston, MA, USA), UCL (UK), and NDRE (Norway). My task here was to study the traffic profile of packet speech traffic in the network. The programming to be done in this context was, as previously mentioned, a good example of resource sharing – the original paradigm the ARPANET built on.

After the SATNET project came to an end in 1979/80, it was put into experimental operations to interconnect local area networks (LANs) at NDRE and UCL with ARPANET. In 1982 I moved over to Telenor R&D, and continued the collaboration with the DARPA community from this location. Moving to Telenor R&D enabled me to create a small Norwegian internet, interconnecting LANs located at the universities

in Oslo, Trondheim and Bergen, and at Telenor R&D, and from there on to SATNET and then on to the US.



⁶ [The colleague \(Mr Kongsberg\) was focused on building the custom made hardware for the 1822 interface, to connect our local proprietary computer to the ARPAnet.](#)



The tendency (most in Europe, due to the big local telecom monopolies) were the OSI⁷ protocols. They didn't believe in TCP/IP. I was living 10 years ahead than others who were insisting with the OSI protocols. I had to work alone, I didn't get funding or my colleagues to participate.

Who are some key people in the development of Internet, leaders or trendsetters?

The development of computer networks was in many ways inspired by **JCR Licklider**'s vision presented in the seminal paper "Man - Computer Symbiosis" from March 1960. Independently of one another, **Paul Baran**, then at Rand Corporation, **Len Kleinrock** at UCLA, and **Donald Davies** at NPL in England, in the 1960s, studied different aspects of message/packet switching. In 1965 **Larry Roberts**, then at Lincoln Lab, was awarded funding from DARPA for an experimental project developing the functionality to exchange digital information over a dial-up phone line between a computer at Lincoln Lab and a computer at SDC in Santa Monica. Shortly after he had demonstrated this capability, in 1966, he was asked to join the IPTO office at DARRPA to lead the new project to develop a wide area digital communications network, that later was named ARPANET.

After having managed the project and seen a reasonable mature ARPANET in operation, interconnecting hosts distributed across the American continent, Larry Roberts left DARPA in 1973 to become President of Telnet, providing commercial data communication

⁷ OSI: Open Systems Interconnection. Was an ISO Standard promoted by telecom companies, and competing with the TCP/IP until the early 1992.



services based on the X.25 standard. This is kind of strange. The X.25 standard is based on connection-oriented transmission in the network, promoted very strongly by the standardizations community, while the emerging technology in the DARPA community and the soon-to-be foundation for the internet technology was based on the datagram paradigm. These two communities were strongly opposed to one another, like cats and dogs. Does this mean the Larry Roberts at that time did not believe in the datagram concept?

Robert Kahn, with experience from BBN in designing and specifying the ARPANET IMPs, joined the IPTO office in 1972, and later became its director. In 1973 he and **Vint Cerf**, then an assistant professor at Stanford, conceived the main principles the internet should build on, and that was published in May 1974. These two people were the driving force behind the internet development.

In another way: **Peter Kirstein** in London, brought the ARPAnet to Europe. In the scandinavian Norway I would mention to **Petter Kongshaug**.

But there are numerous other people that have contributed to this development, all in a giant symphony conducted by Bob Kahn and Vint Cerf. May be I should mention one person that have had an enormous impact on the usability of the internet, namely **Tim Berners-Lee** and his invention of the Web.

Two anecdotal situations

Landing in Los Angeles in 1977 to attend an ARPA-meeting somewhere in California, and discovering that I had forgotten to bring with me the meeting information. Luckily I found my way to ISI where a friendly PhD-student let me in and gave me access to a terminal, so that I could read my mail and get the meeting information. By the way, ISI was at that time hosting my email account.

Around November the 1st-1983 **Ronald Mark Austin**, a 19-years old student at UCLA, was arrested and charged with illegal access to and theft from a large number of computer systems connected to the ARPANET. Among those were several systems belonging to the American defense. It was also believed that Austin had broken into the main campus system at Kjeller Norway, which served both the Norwegian Defense Research Establishment (NDRE), The Norwegian Air Force base at Kjeller, and Oslo University, according to one of the Norwegian newspapers - blowing up the story in large headlines. It turned out to be my VAX-750 that was invaded, used for my collaboration with the ARPA community, and contained neither defense secrets nor other sensitive material. I had a hard time



responding to all phone calls received from national security people, the research institutes at Kjeller, the Defense Security Agency, and lots of newspapers. In addition I received a subpoena from the Court in Los Angeles. When they learned about the real situation, the subpoena was of course cancelled.

What do you think about the future of Internet?

The internet will increasingly encapsulate the whole world, gradually converting it into the so-called global village. It will enable people from different cultures to access the same global information base and provide them with an easy way to communicate and exchange view, and thereby hopefully reduce the tensions between the people/cultures of the global village and enable peaceful coexistence.

But the

The internet is penetrating into all aspects of our society, making the mankind increasingly dependent on the reliable and secure operations of the network and its services. This is a heartbreakingscary situation, since software—adequate quality and, reliability, and adequate—security—meansrobustness against failures and hacking, of our networks and information systems are not yet in place.

The future of the internet is something you can't imagine. Communications are cheap enough, that parents, grandparents and children they can freely communicate with the family if abroad, and this in turn is changing all our societies.

Do you see any technological trends?

The internet is mostly based on a fiber-optical transmission network, where the capacity of the transmission network is steadily being increased by refining the DWDM⁸ technique.

Going back to the mid-70s and the harsh struggle between the standardization community and the DARPA community, the two communication directions (virtual lines and datagram), both had their advantageous and disadvantageous. DARPA at that time was strongly advocating against virtual lines. It is therefore interesting to observe the effort, in the last decade or so, to integrate the advantageous of virtual lines into the internet without compromising the datagram concept.

⁸ DWDM: Stands for Dense Wave Division Multiplexing. A way to increase the amount of information transmitted through a communications channel.



I think her on the introduction of Multi-Protocol-Label-Switching (MPLS) and queue controls in the routers, in order to fulfill real-time and other quality of service transmission issues.

The internet users are steadily being more mobile, wanting to use internet service – including voice calls – from anywhere and at any time. We will see the development of more suitable PDAs, with expanded capacity and lower power consumption, combining phone, voice conferencing, and normal internet services. Such devices will not only be used to access the internet, but will increasingly be used for mobile-to-mobile communications.

Computing elements will increasingly be embedded in things like airplanes, cars, home appliances, in farming, in the industry, in the medical world, in other words be part of the personal, commercial, and public domains. That means we will be more and more dependent on the reliable functioning of such electronic elements containing more or less complexreliable software. We are not that far yet, and will see an increased focus on methods and tools for the development of robust and reliable software.

ADDITIONAL READING

PAPERS & BOOKS MENTIONED / RECOMMENDED

Pål Spilling & Yngvar Lundh 2004. "Features of the Internet history The Norwegian contribution to the development" *Teletronikk* March 2004. Pages 113 to 133. 20 pages)